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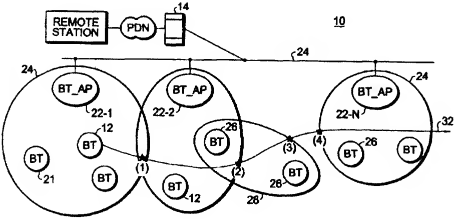
(54) Title: METHOD AND APPARATUS FOR PERFORMING HANDOVER IN A RADIO COMMUNICATION SYSTEM



(57) Abstract: A method, and associated apparatus, facilitates handover of communications with a mobile Bluetooth device (12) operable to communicate packet data with other Bluetooth devices (12, 26). Handover of communications is effectuated between fixed-infrastructure access points (22) or other mobile Bluetooth devices (12, 26) formed in a scatternet. The device (12, 26) to which communications are to be handed-over becomes a slave to the Bluetooth device (12) with which communications are ongoing, thereby to permit time synchronization thereto.

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Minimum documentation searched (classification system followed by classification symbols)
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C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 026 297 A (HAARTSEN JACOBUS CORNELIS) 15 February 2000 (2000-02-15) column 2, line 37 -column 3, line 25	1,4,8, 10,12,18
A	column 5, line 52 -column 6, line 64	2,3,5-7, 9,11, 13-17, 19,20
E	WO 01 78246 A (ARAZI NITZAN ;BARAK HAIM (IL); COMMIL LTD (IL); FRIEDMAN MARK M (I) 18 October 2001 (2001-10-18) page 5, line 17 -page 9, line 4	1,6,12, 18

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance
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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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X	ALBRECHT M ET AL: "IP services over Bluetooth: leading the way to a new mobility" LOCAL COMPUTER NETWORKS, 1999. LCN '99. CONFERENCE ON LOWELL, MA, USA 18-20 OCT. 1999, LOS ALAMITOS, CA, USA,IEEE COMPUT. SOC, US, 18 October 1999 (1999-10-18), pages 2-11, XP010358529 ISBN: 0-7695-0309-8 the whole document	1,18
A	GARG S ET AL: "MAC SCHEDULING POLICIES FOR POWER OPTIMIZATION IN BLUETOOTH: A MASTER DRIVEN TDD WIRELESS SYSTEM" VTC 2000-SPRING. 2000 IEEE 51ST. VEHICULAR TECHNOLOGY CONFERENCE PROCEEDINGS. TOKYO, JAPAN, MAY 15-18, 2000, IEEE VEHICULAR TECHNOLGY CONFERENCE, NEW YORK, NY: IEEE, US, vol. 1 OF 3. CONF. 51, 15 May 2000 (2000-05-15), pages 196-200, XP000970607 ISBN: 0-7803-5719-1 the whole document	1-20

INTERNATIONAL SEARCH REPORT

Information on patent family members

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			BR	9812219	A	18-07-2000
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			AU	4927401	A	23-10-2001
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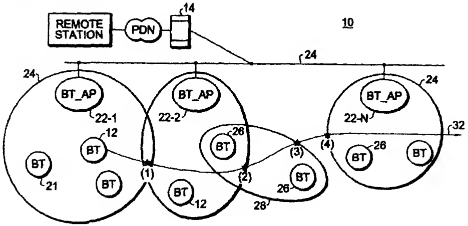
(54) Title: METHOD, AND ASSOCIATED APPARATUS, FOR EFFECTUATING HANDOVER OF COMMUNICATIONS IN A BLUETOOTH, OR OTHER, RADIO COMMUNICATION SYSTEM



(57) Abstract: A method, and associated apparatus, facilitates handover of communications with a mobile Bluetooth device (12) operable to communicate packet data with other Bluetooth devices (12, 26). Handover of communications is effectuated between fixed-infrastructure access points (22) or other mobile Bluetooth devices (12, 26) formed in a scatternet. The device (12, 26) to which communications are to be handed-over becomes a slave to the Bluetooth device (12) with which communications are ongoing, thereby to permit time synchronization thereto.

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METHOD, AND ASSOCIATED APPARATUS, FOR EFFECTUATING HANDOVER OF COMMUNICATIONS IN A BLUETOOTH, OR OTHER, RADIO COMMUNICATION SYSTEM

The present invention relates generally to a manner by which to handover communication with a mobile Bluetooth-compatible (BT), or other communication, device from an active communication device to a target communication device. More particularly, the present invention relates to a method, and an associated apparatus, for facilitating handover of communications of the mobile Bluetooth, or other, device from an active piconet to a target piconet. Handover of communications is possible in a Bluetooth scatternet which lacks a fixed infrastructure as well as a Bluetooth system having access points forming a fixed infrastructure, or a combination thereof.

BACKGROUND OF THE INVENTION

The use of multi-user radio communication systems has achieved wide popularity in recent years as advancements in communication technologies have permitted the affordable utilization of such communication systems by large numbers of users to communicate therethrough.

Like other types of communication systems, a radio communication system is formed, at a minimum, of a sending station and a receiving station interconnected by way of a communication channel. In a radio communication system, the communication channel is formed of a radio communication channel. A radio communication channel is defined upon a portion of the electromagnetic spectrum. A communication

channel defined in a wireline communication system, in contrast, is defined upon a wireline connection extending between the sending and receiving stations. Because a radio communication channel defined upon a portion of the electromagnetic spectrum is used to communicate communication signals between the sending and receiving stations, the need for wireline connection between the sending and receiving stations of a conventional wireline communication system is obviated. The use of a radio communication system to communicate therethrough, as a result, inherently increases the mobility of communication relative to communications in a conventional wireline communication system.

Digital communication techniques have been implemented in radio, as well as other, communication systems. Digital communication techniques generally permit the communication system in which the techniques are implemented to achieve greater communication capacity contrasted to conventional, analog communication techniques.

In a communication system which utilizes digital communication techniques, information which is to be communicated is digitized to form digital bits. The digital bits are typically formatted according to a formatting scheme. Groups of the digital bits, for instance, are positioned to form a packet of data.

Because packets of data can be communicated at discrete intervals, rather than continuously, a frequency band need not be dedicated solely for the communication of data between one communication pair. Instead, the frequency band can be shared amongst a plurality of different communication pairs. The ability to share the frequency band amongst the more

than one communication pair permits a multiple increase in the communication capacity of the system.

Packet-data communications are effectuated, for instance, in conventional LAN (Local Area Networks). Wireless networks, operable in manners analogous to wired LANs, referred to as WLANs (Wireless Local Area Networks) have also been developed and are utilized to communicate data over a radio link. Some of such systems are able to provide for voice, as well as non-voice, communications.

A communication standard, referred to as Bluetooth, has been promulgated which provides a standard operating protocol by which to communicate data over a relatively short distance, e.g., about ten meters. The Bluetooth communication standard provides a manner which enables seamless voice and data communication by way of short-range radio links and permits a broad range of devices to be connected easily and quickly by way of the radio links. Proposals have been set forth to provide a wide array of devices with Bluetooth communication capabilities. Mobile computers and mobile phones are exemplary of devices which have been proposed to make use of the Bluetooth communication standard.

An advantageous characteristic of the Bluetooth communication standard is the ability to provide combined usability models based upon functions provided by different devices. For instance, using Bluetooth-based communication signals, a communication path can be formed between a PDU (Personal Data Unit) and a cellular phone. And, a second communication path is also formable between a cellular phone and a cellular base station, thereby providing connectivity for both data and voice communication. In this

exemplary implementation, the PDU maintains its function as a computing device and the cellular phone maintains its function as a communication device, while each of the devices provides a specific function efficiently by way of the Bluetooth communication scheme.

Multi-point connections are also provided through the use of a Bluetooth-based communication scheme. While the radio range envisioned pursuant to the Bluetooth communication standard is relatively small, i.e., on the order of ten meters, Bluetooth-based devices can, appropriately positioned, act as bridges to extend the range of the communication of the Bluetooth-based communication signals.

A WIO (Wireless Intranet Office) is also exemplary of a communication system in which Bluetooth-compatible devices can be utilized. In a WIO, typically, voice, and other real-time, communications are provided through the use of a mobile station. Voice communication by way of a WIO provides the advantages of use of a wireless communication system in a cost-effective manner. Voice, as well as other data, can be communicated between mobile stations operable in such a system.

The Bluetooth communication standard defines a piconet, formed of two or more Bluetooth-compatible devices which share a common communication channel. In a WIO or WLAN, the piconet architecture defined in the Bluetooth communication standard is integrated into the WLAN through the introduction of an access point (AP). An access point defines a logical point at which data unit of the wired portion of the LAN enters the piconet defined in the Bluetooth communication standard.

By positioning a plurality of access points at a plurality of spaced-apart locations, a mobile station exiting a communication range encompassed by a first access point enters the communication range encompassed by a second access point.

Analogous to operation of a mobile station in a conventional, cellular communication system in which communication handovers are effectuated to permit continued communication by the mobile station as the mobile station moves throughout a geographical area, a mobile station operable in the LAN similarly would be permitted continued communication if handover of communications between access points would be possible.

While currently, the Bluetooth communication standard does not define a handover method, a manner by which to handover communications of a mobile station from one piconet to another would advantageously facilitate communications in a Bluetooth-compatible communication system.

It is in light of this background information related to wireless communication systems that the significant improvements of the present invention have evolved.

SUMMARY OF THE INVENTION

The present invention, accordingly, advantageously provides a method, and associated apparatus, by which to handover communications with a mobile communication device, such as a mobile Bluetooth-compatible device, or other communication device, from an active communication device to a target communication device.

Through operation of an embodiment of the present invention, handover of communication is possible between Bluetooth scatternets, or other networks which lack fixed infrastructures. Handover of communications is also possible in a Bluetooth, or other, system having access points forming a fixed infrastructure, as well as also in a system having both scatternets and a fixed infrastructure.

In one aspect of the present invention, apparatus, and an associated method, is provided by which to handover communications with a mobile Bluetooth from one piconet to another in a manner both to permit continued communication as well as to limit packet loss during the handover.

When handover is to be effectuated between successive access points of a Bluetooth-compatible WLAN, the mobile Bluetooth device forming the mobile station is initially a slave to the access point with which the mobile Bluetooth device communicates. When the mobile Bluetooth device travels into an area encompassed by another access point, a handover of communications from the first access point to the subsequent access point is generally desired. Measurements are performed during operation of the mobile Bluetooth device. For example, measurements are made to determine when a handover should be initiated. In one implementation, power levels, or other of the signals detected at the Bluetooth device communication quality indicia, are measured at selected intervals.

When the power levels of signals generated by the first access point falls beneath a certain threshold, the Bluetooth mobile device sends an inquiry message to the second access point, forming now a target

access point. The inquiry message inquires of a device address associated with the target access point. When the target access point receives the inquiry, a response is generated, and returned to the mobile Bluetooth device, with the appropriate address and clock information of the target access point. Thereafter, the target access point pushes other Bluetooth devices in the piconet in which the target access point also forms a portion, into reduced-power states, such as SNIFF or HOLD states. If the availability of temporary addresses by which to identify the mobile Bluetooth device is limited, one or more of the other Bluetooth devices associated with the second piconet can be put into a PARK mode by the target access point. When pushed into a PARK mode, the temporary address identifying such Bluetooth device is made available to identify other Bluetooth devices, such as the mobile Bluetooth device of which handover of communications is desired.

In another aspect of the present invention, the master-slave roles of the target access point and the mobile Bluetooth device are exchanged. That is to say, with respect to each other, the mobile Bluetooth device becomes a master and the target access point becomes a slave thereto. The mobile Bluetooth device, prior to the handover, remains as a slave to the access point associated with the first piconet. Time synchronization of the target access point to the mobile Bluetooth device is then effectuated . Because of the time synchronization, the handover of communications from the first piconet to the second piconet can be effectuated without loss of packets of data during the handover due to non-synchronization of timing between the piconets.

In another aspect of the present invention, when selection is made is initiate a handover, the active access point is caused to push all active Bluetooth devices, other than the mobile Bluetooth device and the active access point, into reduced power-level states. Then, the mobile Bluetooth device and the active access point exchange master-slave roles. That is to say, the mobile Bluetooth device becomes a master to the active access point, and the active access point becomes a slave thereto. Thereafter, handover is effectuated of the mobile Bluetooth device from the first piconet to the second piconet and the connection of the mobile Bluetooth device to the first piconet is terminated.

In another aspect of the present invention, handover of communications is effectuated between piconets of a scatternet. Handover of communications is effectuated with a handover of communication from a first piconet to a second piconet. The mobile Bluetooth device and a master device of the second piconet exchange master-slave relationships with respect to each other. Once the mobile Bluetooth device becomes a master with respect to the device which becomes its slave, the mobile Bluetooth device causes such other device to become time synchronized thereto. Thereafter, handover of communications to the second piconet is effectuated.

Because a manner is provided by which to facilitate handover of communications between piconets of a Bluetooth communication system, the convenience of use of the Bluetooth communication system is facilitated.

In these and other aspects, therefore, a method, and associated apparatus, is provided for handing over

communications of a mobile communication device initially operable in a connected state in a first piconet to a second picnoet, thereafter to be operable in a connected state in the second piconet. The first piconet includes at least one first- piconet communication device and the second piconet includes at least one second-piconet communication device. The initiation of handover of communications from the first piconet to the second piconet is selected responsive to a communication indicia representative of communications with the mobile communication device. The at least one second-piconet communication device is caused to be come time-synchronized with the communication device. Thereafter, communications with the mobile communication device by way of the second piconet is effectuated. Thereby, the mobile communication device is operated in the connected state in the second picnoet.

A more complete appreciation of the present invention and the scope thereof can be obtained from the accompanying drawings which are briefly summarized below, the following detailed description of the presently-preferred embodiments of the invention, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWING

Figure 1 illustrates a functional diagram of a Bluetooth communication system forming a WLAN (Wireless Local Area Network) in which an embodiment of the present invention is operable.

Figure 2 illustrates a portion of the communication system shown in Figure 1, here representing initial positioning of a mobile Bluetooth device during a communication session.

Figure 3 also illustrates a portion of the communication system shown in Figure 1, here representing positioning of the mobile Bluetooth device when the device is repositioned at a location at which ~~a handover of~~ communications is desired.

Figure 4 also illustrates a portion of the communication system shown in Figure 1, here also representing positioning of the mobile Bluetooth device at a position at which handover is desired and in which additional Bluetooth devices are located at the piconet to which the communications are to be handed over during operation of an embodiment of the present invention.

Figures 5A-B illustrates a message sequence diagram representing messaging generated during operation of an embodiment of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring first to Figure 1, a communication system, shown generally at 10, provides for communication of data with a mobile Bluetooth device 12 operable in a Bluetooth-compatible WLAN (Wireless Local Area Network), or the like. The fixed infrastructure of the WLAN is coupled, by way of a gateway 14 to a packet data network 16, such as the Internet. A remote station 18 is also coupled to the packet data network. A communication path formed upon a radio link formed between the mobile Bluetooth

device 12 and the network infrastructure of the WLAN, and through the WLAN, the gateway 14, and the packet data network 16 permits communications to be effectuated, for instance, between the mobile Bluetooth device 12 and the remote station 18.

The network infrastructure of the WLAN is here shown to include a plurality of access points 22-1 through 22-N, each of which is connected by way of a line 24. Each of the access points 22 defines a coverage area 24, herein referred to as a cell. Coverage areas of adjacent ones of the access points 22 partially overlap.

The WLAN forms a multi-user system permitting a plurality of users, here Bluetooth devices, to communicate by way of the WLAN. In the exemplary illustration of the figure, the first cell 24 also includes an additional two Bluetooth devices 26, the second the cell 24 also includes two additional two Bluetooth devices 26, and the Nth cell 24 also includes two Bluetooth devices 26. The Bluetooth devices of each of the cells 24 defines a piconet, operable pursuant to the Bluetooth communication standard.

A piconet need not include a network infrastructure device, such as an access point 22. A piconet, here referenced by 28, is formed, of any two or more Bluetooth devices including a master Bluetooth device and up to seven slave Bluetooth devices. Piconets are dynamically configurable, and reconfigurable, again all pursuant to the Bluetooth communication standard. As set forth in the standard, a Bluetooth device can, concurrently, form a portion of more than one piconet. And, the device may form a master Bluetooth device of one piconet and a slave

Bluetooth device of another piconet. Advantage is taken of this capability of a Bluetooth device during operation of an embodiment of the present invention.

A mobile Bluetooth device is permitted movement throughout an area, here at the least the area encompassed by the WLAN forming a portion of the communication system. Here, the Bluetooth device 12 travels along the path 32, and, during such travel, the Bluetooth device travels through a plurality of cells-piconets 24-28. As the Bluetooth device 12 travels, handover of communications from one piconet to another is effectuated pursuant to operation of an embodiment of the present invention.

Figure 2 illustrates two of the access points, access points 22-1 and 22-2 and the respective cells 24 defined by the coverage areas of the access points. Overlapping portions 36 of the two cells 24 are shown in the figure. The mobile Bluetooth device 12 travels along a path indicated by the arrow 32. As shown, the path along which the device 12 travels causes the mobile Bluetooth device to travel through the area 36 and into the cell 24 defined by the second access point 22-2. When initially-positioned, as shown, the mobile Bluetooth device is initially in a connected state with the first access point 22-1. Conventionally, the access point 22-1 forms a master and the mobile Bluetooth device forms a slave thereto. When the mobile Bluetooth device is in a connected stated with the access points 22-1, the mobile Bluetooth device is maintained in time synchronization with the access points.

Figure 3 illustrates subsequent positioning of the mobile Bluetooth device 12 at the area 36 formed of the overlapping coverage areas of the first and

second access points 22-1 and 22-2. The mobile Bluetooth device is operable to determine that a handover of communications is desired, such as by way of measuring power levels, or other communication indicia, of signals transmitted by the access points 22-1 and 22-2. When the power level, or other communication indicia, is greater than a selected threshold, selection of handover is initiated. In addition, the mobile Bluetooth device can enter the inquiry state whenever it likes. For instance, if the signal magnitude of signals generated by the access point 22-1 is weak, i.e., beneath a threshold, the mobile Bluetooth device searches for other possibilities including a new AP, piconet, etc. Establishment of a new connection with the access point 22-2 is attempted by the mobile Bluetooth device pursuant to an INQUIRY process. An INQUIRY message is sent by the mobile Bluetooth device to the access point 22-2 to inquire of a device address identifying the access point. When the access point detects the INQUIRY message, an INQUIRY response message is generated and returned to the mobile Bluetooth device. The INQUIRY response message includes the address and clock information associated with the second access point.

Time synchronization is generally not maintained between piconets, including the piconets which include respective ones of the access points 22. As a result, although the mobile Bluetooth device 12 is time-synchronized to the access point 22-1 of the first piconet, the mobile Bluetooth device is not time-synchronized to the piconet of which the access point 22-2 forms a portion. To be recognized as a Bluetooth unit associated with the second access point 22-2, the

Bluetooth device should be synchronized together with the access point 22-2. When time-synchronized to the piconet of which the access point 22-2 forms a portion, it is necessary to have a time synchronization because of the frequency hopping system. The frequency hoppin sequence is generated from the address and clock timing. To be recognized as a Bluetooth unit, an internal clock of the mobile Bluetooth device corresponds with the clock of the access point 22-2.

During operation of an embodiment of the present invention, when handover of communications is selected to be initiated, the access points 22-2, forming the master Bluetooth device relative to other Bluetooth devices 26 in the piconet, causes such other Bluetooth devices 26 to enter a reduced power-level state. Such Bluetooth devices are caused, for instance, to enter the SNIFF or HOLD modes, both defined in the Bluetooth communication standard. As each Bluetooth device is identified by a MAC address, also described as an active member address (AM_ADDR), if the availability of MAC addresses is limited, some of the Bluetooth devices 26 are selectably alternately caused to enter a PARK mode, as also defined in the Bluetooth communication standard. When a Bluetooth device is caused to enter the PARK mode, the device releases the MAC address (i.e., AM_ADDR) by which the device is identified. When the MAC address (i.e., AM_ADDR) is released, the address can be reused to identify another Bluetooth device. In a system in which tiers of service, analogous to QoS (Quality of Service) are defined, Bluetooth devices to which lower-tier services are provided are first pushed into the PARK mode while Bluetooth devices to which higher-tiers of

service are provided are more likely to be prevented from entering the PARK mode.

Currently, the mobile Bluetooth unit 12 is a master of the access point 22-2 and the access point 22-2 is a slave of the mobile Bluetooth unit 12. Once the other Bluetooth devices 26 have been caused to enter a reduced power-level mode, the master-slave roles of the mobile Bluetooth device 12 and the access point 22-2 are exchanged. That is to say, with respect to one another, the mobile Bluetooth device 12 becomes a slave to the access point 22-2. And, at the same time, the Bluetooth device 12 remains a slave to the first access point 22-1 and remains time-synchronized with the access point 22-1. But, the mobile Bluetooth device 12 becomes a slave of the access point 22-2, and the time synchronization of the second piconet so defined is effectuated with respect to a second clock. Once this connection between the mobile Bluetooth device 12 (a slave) and the access point 22-2 is completed, the mobile Bluetooth device 12 is disconnected out of a communication link for the first access point 22-1 of the first piconet.

While the just-described, exemplary implementation describes operation in which the mobile Bluetooth device requests the exchange of master-slave roles with the access point 22-2, in another implementation, the access point 22-2 controls all the Bluetooth devices within its cell 24, and the access point 22-2 is aware of an appropriate timing scheme which shall accept the mobile Bluetooth device 12.

Figure 4 again illustrates positioning of the mobile Bluetooth device 12 at the area 36, here also subsequent to selection of initiation of handover of communications from the first access point 22-1 to the

second access point 22-2. Figure 4 represents alternate operation of an embodiment of the present invention. Here, the mobile Bluetooth device maintains its connection with the first access point 22-1 after a connection with the second access point 22-2. By maintaining connections with both of the access points, the possibility of loss of packets of data is reduced. Here, the other Bluetooth devices 26 located in the coverage area encompassed by the access point 22-1 are pushed into reduced power-level modes. That is to say, the other Bluetooth devices are pushed into a SNIFF, a HOLD, or PARK mode, again, according to a tier-of-service pursuant to which such Bluetooth devices are operable. Then, the mobile Bluetooth device 12 and the first access point 22-1 exchange master-slave roles such that the Bluetooth device 12 becomes the master of the access point 22-1 and the access point becomes a slave thereto. The access point 22-1 remains a master to the other Bluetooth devices 26. Subsequent to completion of handover of communications, the Bluetooth device 12 terminates the connection with the access point 22-1.

The message sequence diagram, shown generally at 52, of Figure 5, illustrates messaging generated during operation of an embodiment of the present invention by which communications with the mobile Bluetooth device 12 are handed over from a first access point 22-1 to a second access point 22-2. It is again noted that, while operation of the exemplary embodiment of the present invention is described with respect to a communication system having a fixed infrastructure, operation is analogously implementable and describable with respect to an infrastructure-free Bluetooth scatternet, or the like.

As noted previously with respect to the preceding figures, the mobile Bluetooth device is initially in a connection with the first access point 22-1. The initial connection between a Bluetooth device 12 and the first access point is indicated by the segment 54 in the figure. The second access point 22-2 is also initially in a communication connection with other Bluetooth devices 26 and with which a piconet is formed. Here, the other Bluetooth devices are divided into a first set of Bluetooth devices operable pursuant to a high tier, i.e., a high QoS level, of service and Bluetooth devices operable pursuant to a low tier of service. The connections between the second access point and the Bluetooth devices of the two groups are indicated by the segments 56 and 58 in the figure.

When, and as illustrated previously with respect to Figures 3 and 4, the mobile Bluetooth device 12 is positioned at the area 36 (shown in Figures 2-4) at which selection is made to initiate handover of communications from the first access point to the second access point, an INQUIRY message is generated by the mobile Bluetooth device and transmitted to the second Bluetooth device. The inquiry message is indicated in the figure by the segment 62. The access point provides an INQUIRY response, indicated by the segment 64, which is returned to the mobile Bluetooth device. Responsive thereto, and as indicated by the segment 66, a PAGE message is then transmitted by the mobile Bluetooth device to the second access point 22-2. And, as indicated by the line segment 68, a PAGE response message is returned by the second access point to the mobile Bluetooth device.

Then, and as indicated by the segment 72, a connection is established between the Bluetooth device 12 and the second access point. Details of the establishment of a connection between two Bluetooth devices is described in detail in the Bluetooth communication standard, such as the Bluetooth specification 1.0b. In the connection, the mobile Bluetooth device forms a master device and the second access point forms a slave thereto. Blocks 74 and 76 indicate that the mobile Bluetooth device 12 forms a master for its connection with the second access point and a slave to the first access point 22-1 while the second access point remains a master for the other Bluetooth devices 26 while becoming a slave to the mobile Bluetooth device 12.

Thereafter, LMP messages LMP_SNIFF or LMP_HOLD are sent to the second group of Bluetooth devices 26. Sending of such messages are indicated by the line segment 78 in the figure. LMP_ACCEPTED messages 82 are returned by such Bluetooth devices. Transmission of a LMP_PARK message, indicated by the segment 84, is also shown in the figure. Such message instructs one or more of the other Bluetooth devices into a PARK mode if MAC addresses (i.e., AM_ADDR) are unavailable to be reassigned to, for instance, the mobile communication device. When a Bluetooth device enters a PARK mode, the MAC address used to identify the device is released, thereby to become available for use by another Bluetooth device. A LMP_ACCEPTED message responsive thereto is indicated by the segment 86.

The sequence diagram also illustrates transmission of analogous LMP_SNIFF and LMP_HOLD messages, indicated by the segment 88 transmitted to

the first group of other Bluetooth devices 26. The first group of Bluetooth devices are operated pursuant to other tiers of service, and LMP_ACCEPTED messages generated responsive thereto are indicated by the line segment 92.

The sequence diagram further illustrates a switch request, LMP_SWITCH_REQ message 94 sent by the mobile Bluetooth device 12 to the second access point 22-2 and this message can also be initiated by theaccess point 22-2 to the mobile Bluetooth device 12 and, responsive thereto, an accept message LMP_ACCEPTED, indicated by the segment 96. Finally, subsequent to handover, a disconnect, or remove message is sent by the mobile Bluetooth device to the first access point 22-1, here indicated by the line segment 98.

Thereby, through operation of an embodiment of the present invention, handover of communications from one Bluetooth device to another Bluetooth device is effectuated to permit continued communications with a mobile Bluetooth device. The Bluetooth devices from which, and to which, communications are handed-over form fixed infrastructure devices or mobile devices, or any combination thereof.

The preferred descriptions are of preferred examples for implementing the invention, and the scope of the invention should not necessarily be limited by this description. The scope of the present invention is defined by the following claims.

We claim:

1. A method for handing over communications of a mobile communication device initially operable in a connected state in a first piconet to a second piconet, thereafter to be operable in a connected state in the second piconet, the first piconet including at least one first-piconet communication device and the second piconet including at least one second-piconet communication device, said method comprising:

selecting initiation of handover of communication from the first piconet to the second piconet responsive to a communication indicia representation of communications with the mobile communication device;

causing the at least one second-piconet communication device to become time-synchronized with the mobile communication device; and

effectuating communications with the mobile communication device by way of the second piconet, thereby to operate the mobile communication device in the connected state in the second piconet.

2. The method of claim 1 wherein the at least one second-piconet communication device comprises a second-piconet pre-handover master communication device and at least one pre-handover slave device, and wherein, prior to said operation of causing, said method comprises the additional operation of:

placing the at least one pre-handover slave device in a reduced power level state.

3. The method of claim 2 wherein said operation of causing the second-piconet communication device to become time-synchronized comprises:

making the pre-handover master communication device a slave to the mobile communication device; and

time-synchronizing the slave formed of the pre-handover master device and the at least one pre-handover slave device to the mobile communication device.

4. The method of claim 1 wherein said method of causing the second-piconet communication device to become time-synchronized comprises:

making the second-piconet communication device a slave to the mobile communication device; and

time-synchronizing the slave formed of the second-piconet communication device to the mobile communication device.

5. The method of claim 1 further comprising the additional operation of removing the mobile communication device out of the first piconet subsequent to effectuation of the communications during said operation of effectuating communications.

6. The method of claim 1 wherein the communication indicia responsive to which initiation of handover of communications is selected during said operation of selecting comprises signal power levels of signals detected by the mobile communication device when operated in the first piconet.

7. The method of claim 1 wherein the at least one first-piconet communication device comprises a first-piconet pre-handover master communication device and at least on first-piconet pre-handover slave device and wherein, prior to said operation of causing, said method comprises the additional operation of:

placing the at least one first-piconet, pre-handover slave device in a reduced power-level state.

8. The method of claim 1 further comprising the additional operation, prior to said operation of causing the at least one second-piconet communication device to become time-synchronized of:

making the first-piconet pre-handover master communication device a slave to the mobile communication device.

9. The method of claim 8 wherein the at least one second-piconet communication device comprises a second-piconet pre-handover master communication device and at least one second-piconet slave communication device and wherein, prior to said operation of causing, said method comprises the additional operation of:

placing the at least one second-piconet, pre-handover slave device in a reduced power-level state.

10. The method of claim 9 wherein said operation of causing the at least one second-piconet communication device to become time-synchronized comprises:

making the second-piconet pre-handover master communication device a slave to the mobile communication device; and

time-synchronizing the slave formed of the second-piconet pre-handover master device and the at least one second-piconet pre-handover slave device tot he mobile communication device.

11. The method of claim 9 wherein the second-piconet pre-handover communication device comprises a target access point forming a portion of a network infrastructure, the access point defining a target cell, and wherein said operation of selecting initiation of handover occurs when the mobile communication device enters the target cell.

12. The method of claim 1 wherein the at least one first-piconet communication device, the at least one second-piconet communication device, and the mobile communication device each comprises a Bluetooth-compatible (BT) device, and wherein said operation of selecting initiation of handover comprises selecting initiation of handover of communications from a first BT piconet to a second BT piconet.

13. The method of claim 12 wherein the at least one BT device of which the second piconet is formed comprises a second-piconet pre-handover slave BT device and wherein, prior to said operation of causing, said method comprises the additional operation of:

placing the at least one pre-handover BT slave device in a reduced power-level state.

14. The method of claim 13 wherein the reduced power-level state into which the pre-handover BT slave device is placed comprises a HOLD mode.

15. The method of claim 13 wherein the reduced power-level state into which the pre-handover BT slave device is placed comprises a SNIFF mode.

16. The method of claim 13 wherein the reduced power-level state into which the pre-handover BT slave device is placed comprises a PARK mode.

17. The method of claim 12 wherein each BT device is identified by a temporary identifier selected from a set of temporary identifiers and wherein the reduced power-level state into which the pre-handover BT slave device is placed is a state in which the pre-handover BT slave device is stripped of the temporary identifier.

18. Apparatus for facilitating handing over communications of a mobile communication device initially operable in a connected state in a first piconet to a second piconet, thereafter to be operable in a connected state in the second piconet, the first piconet including at least one first-piconet

communication device and the second piconet including at least one second-piconet communication device, said apparatus comprising:

a handover initiation selector coupled to receive indications of a communication indicia representative of communications with the mobile communication device, said handover initiation selector for selecting initiation of handover of communications from the first piconet to the second piconet responsive to the indications of the communication indicia; and

a time-synchronizer coupled to receive indications of selection by said handover initiation selector of selection of the initiation of handover, said time synchronizer for causing the at least one second-piconet communication device to become time-synchronized with the mobile communication device.

19. The apparatus of claim 18 wherein the at least one second-piconet communication device comprises a second-piconet pre-handover master communication device and at least one second-piconet pre-handover slave device and wherein said time-synchronizer is further for placing the at least one second-piconet pre-handover slave device in a reduced power-level state.

20. The apparatus of claim 19 wherein said time synchronizer makes the pre-handover master communication device a slave to the mobile communication device and time-synchronizes the slave formed of the pre-handover master device to the mobile communication device.

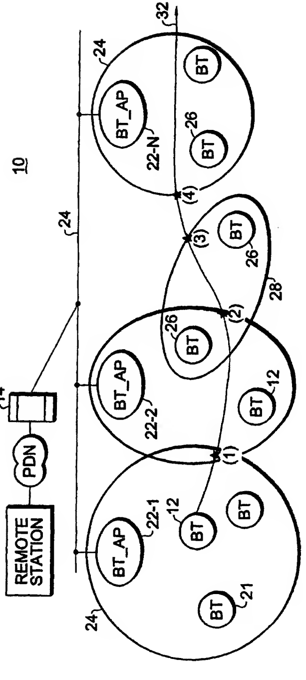
REMOTE STATION
PDN
14
10
24
BT_AP
22-1
22-2
22-N
BT
12
21
26
28
32
(1)
(2)
(3)
(4)

FIG. 1

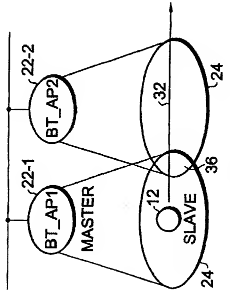
22-1
22-2
BT_AP1
BT_AP2
MASTER
12
SLAVE
32
36
24
24

FIG. 2

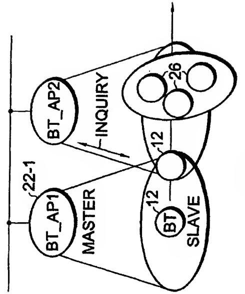
22-1
BT_AP1
BT_AP2
MASTER
INQUIRY
12
12
BT
SLAVE
26

FIG. 3

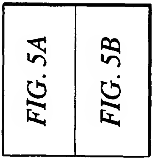

FIG. 5

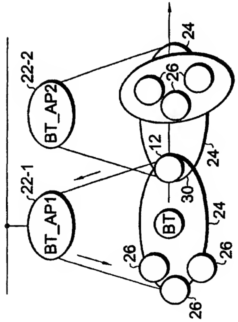

FIG. 4

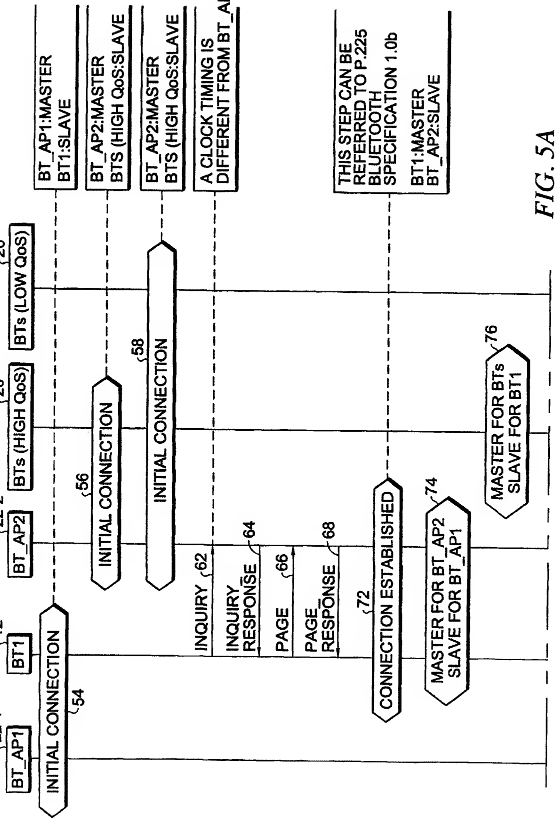
BT_AP1
22-1
BT1
12
BT_AP2
22-2
BTs (HIGH QoS)
20
BTs (LOW QoS)
26
INITIAL CONNECTION
54
INITIAL CONNECTION
56
INITIAL CONNECTION
58
INQUIRY
62
INQUIRY_RESPONSE
64
PAGE
66
PAGE_RESPONSE
68
CONNECTION ESTABLISHED
72
MASTER FOR BT_AP2
SLAVE FOR BT_AP1
74
MASTER FOR BTs
SLAVE FOR BT1
76
BT_AP1:MASTER
BT1:SLAVE
BT_AP2:MASTER
BTS (HIGH QoS:SLAVE
BT_AP2:MASTER
BTS (HIGH QoS:SLAVE
A CLOCK TIMING IS
DIFFERENT FROM BT_AP1
THIS STEP CAN BE
REFERRED TO P.225
BLUETOOTH
SPECIFICATION 1.0b
BT1:MASTER
BT_AP2:SLAVE

FIG. 5A

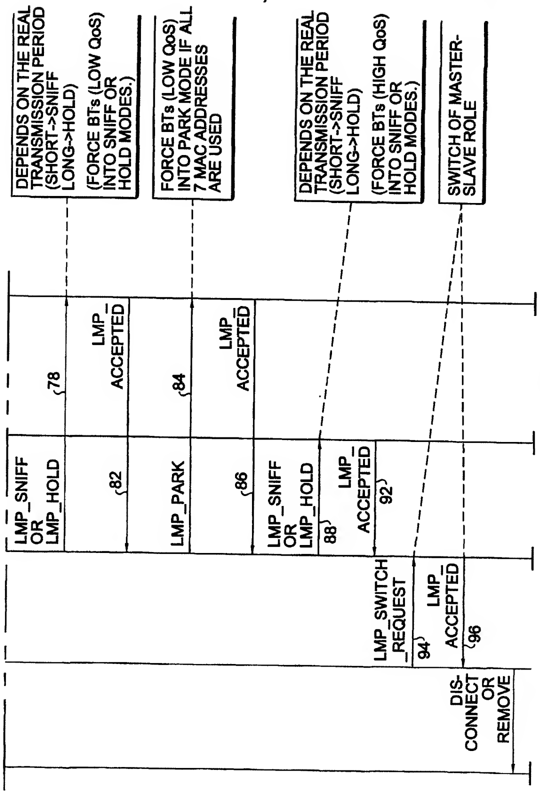
DEPENDS ON THE REAL TRANSMISSION PERIOD (SHORT->SNIFF LONG->HOLD)
(FORCE BTs (LOW QoS) INTO SNIFF OR HOLD MODES.)
FORCE BTs (LOW QoS) INTO PARK MODE IF ALL 7 MAC ADDRESSES ARE USED
DEPENDS ON THE REAL TRANSMISSION PERIOD (SHORT->SNIFF LONG->HOLD)
(FORCE BTs (HIGH QoS) INTO SNIFF OR HOLD MODES.)
SWITCH OF MASTER-SLAVE ROLE
LMP_SNIFF OR LMP_HOLD
78
LMP_ACCEPTED
82
LMP_PARK
84
LMP_ACCEPTED
86
LMP_SNIFF OR LMP_HOLD
88
LMP_ACCEPTED
92
LMP_SWITCH_REQUEST
94
LMP_ACCEPTED
96
DIS-CONNECT OR REMOVE

FIG. 5B

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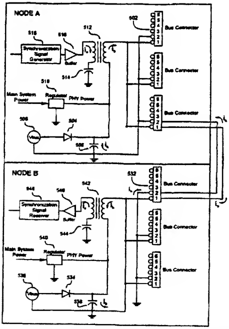
[Continued on next page]

(54) Title: METHOD AND APPARATUS FOR DISTRIBUTED SYNCHRONIZATION SIGNAL



(57) Abstract: A method and apparatus is described for distributing a synchronization signal for deriving sample rate clocks in data transmitted between nodes in a system such as an IEEE 1394 bus-interconnected system. The synchronization signal is coupled onto a conductor of the IEEE 1394 bus by a clock master node, and received by all other nodes. The synchronization signal is coupled to the conductor in the bus without interfering with the signal, such as a power or data signal, carried by that conductor. Each node may derive its sample rate clocks using conventional time stamp means, or optionally referencing its sample rate clocks to the synchronization signal for higher performance. The format of the synchronization signal may be virtually any type of standard or non-standard work clock or longitudinal time code.

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METHOD AND APPARATUS FOR DISTRIBUTED SYNCHRONIZATION SIGNAL

TECHNICAL FIELD

The present invention relates generally to bus system architecture and, more particularly, to a method and apparatus for distributing a synchronization clock signal.

BACKGROUND

Today's consumer electronic devices are increasingly being implemented as special-purpose computer systems, complete with processor, memory, and I/O functionality. The various companies who design and manufacture these devices may have their own particular interconnect technology and communication protocols. Consequently, compatibility problems can occur when connecting devices made by different manufacturers. In home entertainment systems, for example, a DVD player manufactured by one company may be incompatible with an audio surround sound decoder manufactured by another company.

To facilitate today's increasingly complex communication between electronic devices, various standards have been developed. In particular, the IEEE 1394 standard for a High Performance Serial Bus (also known as the "1394" bus) has been established to facilitate the development of compatible consumer electronics devices. In addition to defining a standard bus communications protocol, the 1394 bus architecture also provides for standard connections, with each interconnected device being able to communicate with every other such device without requiring individual point-to-point connections between the various devices. The

IEEE 1394 standard (IEEE 1394-1995 and IEEE 1394a supplement) is entitled "Standard for a High Performance Serial Bus," and is based on the ISO/IEC 13213 (ANSI/IEEE 1212) specification, entitled "Information technology—Microprocessor systems—Control and Status Registers (CSR) Architecture for microcomputer buses."

Referring to Figure 1, a typical home entertainment system 100 is depicted. The system includes a high speed bus, such as an IEEE 1394 bus 102, that interconnects a variety of electronic devices. The particular configuration depicted is intended solely to show the functional interconnection of representative devices. Those skilled in the art understand that the 1394 bus architecture supports tree and daisy chain connection configurations.

A DVD player 104 is included for playing DVD disks and correspondingly outputting MPEG audio/video data streams on the 1394 bus 102. The audio and video data streams are transported over an isochronous channel of the 1394 bus 102, to an MPEG decoder 108 which demultiplexes the MPEG transport stream and transmits the audio elementary stream to the surround sound decoder 106. The MPEG decoder 106 simultaneously decodes the video elementary stream to a video signal which is typically output to a video monitor (not shown in the diagram). A cable or satellite set-top box 110 receives media from a cable or satellite television provider and outputs an audio/video MPEG data stream on an isochronous channel of the 1394 bus 102. The MPEG decoder 108 demultiplexes this data and sends the audio to the surround decoder 106 and decodes and outputs the video signal.

The surround sound decoder 106 receives compressed audio signals from other devices connected to the 1394 bus 102 and decodes the audio. The decoded audio data is then output on the 1394 bus 102 to an amplifier/speaker subsystem 112. The MPEG decoder 108 decodes MPEG transport streams received from various source devices on the 1394 bus 102 and demultiplexes the audio and video. The audio is typically transmitted over the 1394 bus 102 to the surround sound decoder 106. The video is decoded and output to a video monitor for presentation.

A controller 114 provides a point of control for all devices in the system 100. The controller 114 may also provide a user interface to configure the system when various devices are added or removed. The controller typically includes a user interface for adjusting audio volume, turning devices on and off, selecting channels on the set-top box 110, etc. Indeed, the controller may be the only device a user interacts with (other than inserting disks into the DVD player 104).

Each of the interconnected devices shown in the system 100 Figure 1 includes interface circuitry connecting the 1394 bus 102 to the particular application circuitry included in the devices. Such interface circuitry includes both the physical electrical connections (known as the PHY layer) and the data format translation interface (known as the Link layer). Such interface circuitry is well known for those skilled in the art, and the general features of such circuitry need not be described herein.

For video and audio applications, which require constant data transfer rates, it is particularly important that a device receiving such data accurately recover the sample rate clock signal from the device transmitting

such data. This ensures that data buffers in the system do not overflow or underflow, and that the temporal aspects of audio/video performance are not degraded. 1394 bus architecture supports transmission of isochronous data packets including time stamp information that can be used to recover the sample rate clock, such as in accordance with the IEC 61883 standard, entitled "Digital Interface for Consumer Audio/Video Equipment." Because there is no requirement that different data streams be frequency related (i.e., isochronous streams may have free-running sample rates), each receiving device or node must implement a separate clock recovery circuit for each received isochronous channel of the 1394 bus.

Referring to Figure 2, a functional block diagram depicts the prior art approach of providing time stamps and correspondingly recovering a sample rate clock. The interface circuitry included within a transmitting device or node 200 is depicted, as is a portion of the interface circuitry included within the receiving device or node 202. The transmitting node 200 includes a latch 204 that latches a lower portion of the value stored in a cycle time register 206 included within the Link layer of the interface circuitry. The cycle time register is clocked by oscillator 201. The latch 204 latches the cycle time value every predetermined number of cycles of the sample rate clock (such as a digital audio word clock in the case of audio data transmission). A transfer delay value is added to the latched cycle time register value, and the resulting time stamp is inserted into the header of the corresponding isochronous data packet 208. As is known to those skilled in the art, the value of the transfer delay is determined at system initialization or bus reset.

At the receiving device or node 202, the received time stamp is compared with the corresponding lower portion of the value stored in the receiving node's cycle time register 210, clocked by oscillator 211. A comparator 212 produces a pulse signal in the event of equality, which is then input to a phase-locked loop (PLL) circuit 214 to recover the sample rate clock signal. The receiving node's cycle time register value is synchronized to the transmitting node's cycle register value by sending periodic updates to the each register from a "cycle master" node. These updates are sent every 125 microseconds, and oscillators 201 and 211 are specified to have frequency accuracy within 100 parts per million, thereby guaranteeing that the values of cycle time registers 206 and 210 are synchronized to less than one least significant bit (LSB) of the cycle time register. Therefore, this method recovers a sample rate clock signal with average frequency equal to the transmitter's sample rate clock signal, and adjustable resolution of 40.9ns (one LSB of the cycle time register).

The particular approach depicted in Figure 2 has a number of disadvantages. If the stream of time stamps is interrupted for any reason, such as during a bus reset, the pulse signal produced by the comparator 212 experiences drop outs, and the PLL 214 then temporarily loses lock and causes a glitch in the sample rate clock signal. Also, because each node on the bus has a free running oscillator (201 and 211), it is impossible to achieve perfect clock synchronization (exactly equal frequency and 0 degrees phase shift) between the recovered sample rate clocks in different nodes. Consequently, recovered sample rate clocks are prone to jitter and phase errors that degrade the quality of audio and video streams. An additional source of sample rate clock degradation is the retiming that data packets undergo in each node, introducing significant delay to the packets as they are

transmitted over a heavily populated bus, and different delay to data packets transmitted over different paths in the system topology. This introduces significant, and different, delays to the time stamps and cycle time register updates, thereby introducing significant sample rate clock misalignment between nodes in the system. These degradations may render the resulting sample rate clock signals unsuitable for high performance systems.

In traditional digital audio and digital video systems it is common to distribute a synchronization signal separately from the digital audio and video data, as shown in Figure 3. This synchronization signal 302 is generated by a master device 304, and is received by a number of devices 306. The format of synchronization signal 302 may be a longitudinal time code such as the SMPTE (Society of Motion Picture and Television Engineers) Time Code; or a square wave "word clock" with frequency equal to the sample rate of the digital audio/video signal; or a "black" digital audio or video signal. This separate synchronization signal requires a separate connection means, thereby reducing the ease of installation and cost advantages of the all-in-one-cable IEEE 1394 serial bus. The standard IEEE 1394 serial bus cable does not contain unused conductors, therefore it cannot carry a separate synchronization signal. Furthermore, the low driving impedance of the circuitry interfacing to the IEEE 1394 cable signals precludes adding a voltage carrier to the existing signals using conventional signal coupling means.

SUMMARY

In accordance with the present invention, a method is provided for distributing a synchronization signal in a system of data exchanging node circuits interconnected by a bus. The method includes generating the

synchronization signal and coupling the synchronization signal to a portion of the bus that carries another signal, such as a power or data signal. The synchronization signal may include a periodic signal having a frequency proportional to a sampling rate of the data exchanged by the node circuits. Alternatively, the synchronization signal may include a longitudinal time code signal or a data packet carrying a coded message corresponding to the data sample rate.

In accordance with another aspect of the present invention, a system is provided that has a data source coupled by a bus with a data receiver. The system includes a synchronization signal generator that is connected to a first portion of the bus by coupling circuitry. The synchronization signal generator generates a synchronization signal that is coupled to the first portion of the bus by the coupling circuitry, where the first portion of the bus also carries another signal. The system also includes decoupling circuitry that connects a synchronization signal detector with the first portion of the bus and decouples the synchronization signal from the other signal to provide the synchronization signal to the synchronization signal detector. One or both of the decoupling circuitry and synchronization signal detector may be included in the data receiver.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a functional block diagram that depicts a typical IEEE 1394 system.

Figure 2 is a functional block diagram that depicts circuitry for producing time stamps by a transmitting device and circuitry for sample rate clock recovery in a prior art receiving device in an IEEE 1394 system.

Figure 3 is a functional block diagram depicting a typical system with a distributed synchronization signal.

Figures 4-7 are functional block diagrams depicting the standard methods of coupling a DC power signal to a conductor in an IEEE 1394 serial bus cable.

Figures 8-11 are functional block diagrams depicting a synchronization signal coupled to the power conductor in an IEEE 1394 serial bus cable by transmitter nodes, in accordance with an embodiment of the present invention.

Figures 12-15 are functional block diagrams depicting a synchronization signal coupled from the power conductor in an IEEE 1394 serial bus cable by receiver nodes, in accordance with an embodiment of the present invention.

Figure 16 is a functional block diagram depicting an electrical circuit which performs Frequency Shift Keying modulation and demodulation, and which constitutes a preferred embodiment of the present invention.

Figure 17 is a functional block diagram illustrating the connection of a transmitter and a receiver node.

Figure 18 is a functional block diagram illustrating the method of regenerating signal currents.

Figure 19 is a functional block diagram of a system arbitrating for automatic selection of a synchronization signal generator.

DETAILED DESCRIPTION

The following is a description of circuitry and methods for recovering a data sample clock from an isochronous data packet stream. The circuitry and methods are conformable to the applicable IEEE 1394, ISO/IEC 13213, and IEC 61883 standards. In this description, certain details are set forth in order to provide a thorough understanding of various embodiments of the present invention. It will be clear to one skilled in the art, however, that the present invention may be practiced without these details. In other instances, well-known circuits, circuit components, control signals, and timing and communications protocols have not been shown or described in detail in order to avoid unnecessarily obscuring the description of the various embodiments of the invention. The described subject matter relates to technology similar to International Application No. PCT/US99/10805, filed 17 May 1999, and entitled "COMBINED ANALOG/DIGITAL DATA TRANSMISSION SYSTEM," which is incorporated herein by reference.

Figures 4-7 show the conventional methods of coupling a power signal to a pair of conductors in the IEEE 1394 cable. A typical IEEE 1394 node 400 provides one or more bus connectors 402. In Figures 4 and 5, pin 1 of the bus connector 402 is fed with DC power via diode 404 and voltage source 406. Capacitor 408 provides filtering and reserve energy. This voltage is carried over the IEEE 1394 bus cable, to other nodes. In Figures 6 and 7, no power signal is provided. Pin 2 of bus connector 402 provides a ground return path for the DC current. Voltage regulator 410

receives the DC voltage from pin 1 of bus connector 402, and supplies this power to the physical layer interface circuitry.

Figures 8-11 show how the Transmitter Nodes add a synchronization signal to the power conductors in the IEEE 1394 cable. Transformer 512 has been added to the Transmitter Nodes to allow a current, ib, to be modulated onto this DC voltage. The Transmitter Nodes illustrated contain a synchronization signal generator 518 that is buffered by 516 and connected to the primary winding of transformer 512. Capacitors 514 provides DC blocking to prevent the transformer coil from saturating. Capacitors 515 provide DC blocking to isolate power regions on the IEEE 1394 bus. Buffer 516 induces a current, ic, into the transformer 512 primary winding. The current added alternates proportional to the synchronization signal 518. IEEE 1394 connector 502 pin 1 therefore has a combination of DC voltage and current received via diode 504 and alternating current ib received via transformer 512 secondary winding.

. Figures 12-15 show how the Receiver Nodes detect the synchronization signal. The signal is connected to pin 1 of IEEE 1394 bus connector. Transformer 542 has been added to the Receiver Nodes to allow a current, ib, to be demodulated. The Receiver Nodes illustrated contain a synchronization signal detector 548 that is buffered by 546 and connected to the primary winding of transformer 542. Capacitor 544 provides DC blocking to prevent the transformer coil from saturating The current ib from the Transmitter Node energizes the primary winding of transformer 542, causing a current ic to appear in the secondary winding of transformer 542. Current to voltage converter/buffer 546 converts current ic to a voltage, and outputs this to synchronization signal detector 548.

Figure 16 depicts an electrical circuit which performs Frequency Shift Keying modulation and demodulation, and which constitutes a preferred embodiment of the present invention. Alternative means of modulating and demodulating the synchronization signal may be employed, such as Amplitude Shift Keying, Minimum Shift Keying, Gaussian Minimum Shift Keying, direct coupling of the baseband signal, or others known to those skilled in the art. In addition, the functional blocks required to accomplish the generation and detection of the signal may be composed of discrete logic devices, as in Figure 16, or of logic blocks in a Field Programmable Gate Array or an Application Specific Integrated Circuit. Microprocessors or Digital Signal Processors may also be employed to generate or detect the signals, using algorithms embodied in their firmware.

Nodes 500 and 530 exchange a DC voltage and the AC synchronization current over the IEEE 1394 bus cable 520 as described in Figure 17. In the configuration shown, node A 500 is the synchronization signal transmitter, and node B 530 is the synchronization signal receiver. The current generated by the Transmitter Node is reflected by a corresponding current, ib, in the secondary winding of transformer 512 in the Receiver Node. It can be seen that the synchronization signal received by 548 is exactly proportional to the synchronization signal transmitted by 518. Therefore, this system has exchanged a synchronization signal between nodes that can be used to represent digital audio, digital video, and other clocks between nodes.

This method operates over a topology of nodes interconnected via multiple cables. For example, in Figure 17, all bus connectors 502 and 532 may be connected to other nodes via bus cables 520, and portions of

current ib will be transmitted to the other nodes and recovered similarly to node 530. Therefore, this method provides a means to share a synchronization signal amongst a number of nodes.

If synchronization current ib is degraded by splitting it between many nodes, it could be regenerated at each node before being passed on to the next node, using the method illustrated in Figure 18. This method may also be used to minimize electrical noise propagation between nodes, as an alternative to that illustrated in Figure 8.

Those skilled in the art would understand that it is possible to adapt the above-described circuitry and methods for operation over other conductors in the IEEE 1394 bus cable. It is also possible to apply these circuitry and methods to buses and systems other than IEEE 1394, such as the universal serial bus (USB), ethernet, and power distribution systems. The signal transmitted using this invention could be then formatted in accordance with a corresponding communications protocol to convey messages between nodes.

A protocol for manually or automatically selecting the node in the system to serve as the synchronization signal generator could be introduced to simplify system operation. One method to automatically select this generator node is to designate the node with the lowest bus identification number. Alternatively, an operator could input command to the system specifying the identity of the synchronization signal generator node.

Figure 19 shows an example system 600 with five nodes 601-605. As is standard on a IEEE 1394 bus, each node is assigned an

identification number sequentially from 0 to N-1, where N is equal to the number of nodes on the bus. Each node on the bus that is capable of generating a synchronization signal advertises its capability at a known address within its address space. Any node 601-605 on the bus can, with a single memory read, determine if other nodes are capable of serving as a synchronization signal generator. At the completion of a bus reset (at which time the topology is stable), each potential synchronization generator 603 and 605 queries other nodes on the network to discover if a synchronization generator with a lower node number exists. The synchronization signal generator node 603 with the lowest node number will not find another synchronization generator with a lower identification number, and will therefore automatically become the synchronization signal generator. The node 605 with a higher node number than the other synchronization generator node 603 will automatically become a synchronization receiver.

In a heterogeneous network, not all synchronization generators may have the same capability. People configuring the network may wish to select a different synchronization generator than the one that would be selected automatically. This may be done by polling the complete network, and requesting all other nodes, apart from the one desired, to no longer advertise their synchronization generator capability on the network. Causing a bus reset will then move the clock source to the remaining node.

In case of user error, and all nodes are disabled, if a possible source node is unable to determine an available source node, it will remove the restriction, and then cause a bus reset. Since all source nodes take the same action, this is equivalent to setting the network back to automatic selection.

Of course this is just one method to automatically select a synchronization signal generator, and those skilled in the art will understand that it is possible to apply other algorithms for selecting a generator.

Several types of devices could be implemented using this technology. A hub device could be implemented that serves as the synchronization signal generator node, with receive-only nodes connected to it. Alternatively, each node could be configured to serve as sender or receiver of the synchronization signal by swapping buffer 516 for buffer 546 and synchronization signal generator 518 for synchronization signal receiver 548 with a simple switching network.

From the foregoing, it will be appreciated that, although specific embodiments of the invention have been described above for purposes of illustration, various modifications may be made to these embodiments without deviating from the spirit and scope of the invention. Those skilled in the art will understand that any of a wide variety of circuit topologies could be employed to couple and decouple synchronization signals to signal lines carrying other signals. Also, many of the above-described circuit embodiments could instead be performed in software. Indeed, numerous variations are well within the scope of the invention, and the invention is not limited except as by the appended claims.

CLAIMS

1. A method of providing a synchronization signal in a system of data exchanging node circuits interconnected by a bus, the method comprising:

generating the synchronization signal;

coupling the synchronization signal to a portion of the bus carrying another signal;

receiving the coupled signals; and

decoupling the synchronization signal from the other signal.

2. The method of claim 1 wherein the other signal includes a power signal.

3. The method of claim 1 wherein the other signal includes a data signal.

4. The method of claim 1 wherein generating the synchronization signal includes generating a periodic signal having a frequency proportional to a sampling rate of the data exchanged by the node circuits.

5. The method of claim 1 wherein generating the synchronization signal includes generating a longitudinal time code signal.

6. The method of claim 1 wherein generating the synchronization signal includes generating the synchronization signal at a manually selected one of node circuits.

7. The method of claim 1 wherein generating the synchronization signal includes generating the synchronization signal at an automatically selected one of node circuits.

8. The method of claim 1 wherein the coupled signals are received at each of the node circuits.

9. The method of claim 1, further comprising:

regenerating the synchronization signal; and

recoupling the synchronization signal to the portion of the bus carrying the other signal.

10. The method of claim 1 wherein the bus is an IEEE 1394 bus.

11. In a system including a data source coupled by a bus with a data receiver, the data source producing a stream of isochronous data packets having associated time stamp values, and the data receiver receiving the isochronous data packets, a method for the data receiver to recover a data sample rate, comprising:

selecting one of first and second data sample rate recovery methods;

if the first method is selected, then recovering the data sample rate corresponding to the received time stamp values; and

if the second method is selected, then:

generating a synchronization signal corresponding with the data sample rate;

coupling the synchronization signal to a portion of the bus carrying another signal;

receiving the coupled signals at the data receiver; and

decoupling at the data receiver the synchronization signal from the other signal.

12. The method of claim 11 wherein the other signal includes a power signal or a data signal.

13. The method of claim 11 wherein generating the synchronization signal includes generating a periodic signal having a frequency proportional to the data sample rate.

14. The method of claim 11 wherein generating the synchronization signal includes generating a longitudinal time code signal corresponding to the data sample rate.

15. The method of claim 11 wherein generating the synchronization signal includes generating a data packet carrying a coded message corresponding to the data sample rate.

16. The method of claim 11 wherein the data source includes an audio source, and the data receiver includes an audio receiver.

17. The method of claim 11, further comprising:

receiving the coupled signals at the data source; and

decoupling at the data source the synchronization signal from the other signal.

18. The method of claim 11, wherein the synchronization signal is generated and coupled to the bus at the data source.

19. The method of claim 11, wherein the bus is an IEEE 1394 bus.

20. A system having a data source coupled by a bus with a data receiver, the data source producing a stream of data packets and the data receiver receiving the data packets, the system further comprising:

a synchronization signal generator operable to produce a synchronization signal;

coupling circuitry connecting the synchronization signal generator to a first portion of the bus, the coupling circuitry being operable to couple the synchronization signal with another signal carried on the first portion of the bus;

a synchronization signal detector; and

decoupling circuitry connecting the synchronization signal detector with the first portion of the bus, the decoupling circuitry being operable to decouple the synchronization signal from the other signal and to provide the synchronization signal to the synchronization signal detector.

21. The system of claim 20 wherein the coupling circuitry includes a transformer.

22. The system of claim 20 wherein the decoupling circuitry includes a transformer.

23. The system of claim 20 wherein the synchronization signal detector is included within the data receiver.

24. The system of claim 20 wherein the decoupling circuitry is included within the data receiver.

25. The system of claim 20 wherein the other signal carried on the first portion of the bus includes a power signal.

26. The system of claim 20 wherein the other signal carried on the first portion of the bus includes a data signal.

27. The system of claim 20 wherein the synchronization signal includes a periodic signal having a frequency proportional to a sampling rate of the data transmitted by the data source.

28. The system of claim 20 wherein the synchronization signal includes a data packet carrying a coded message corresponding to a sampling rate of the data transmitted by the data source.

29. The system of claim 20 wherein the data packets are isochronous data packets having associated time stamp values, and wherein the data receiver includes circuitry operable to receive the time stamp values and responsively recover a sampling rate of the data transmitted by the data source.

30. The system of claim 20 wherein the bus is an IEEE 1394 bus.

31. A home entertainment system, comprising:

an audio/video source operable to produce a stream of data packets having associated time stamp values;

an audio/video receiver operable to receive the stream of data packets;

a bus coupling the audio/video source and receiver; and

a synchronization signal generator coupled with a first portion of the bus and operable to produce a synchronization signal that is coupled with another signal carried on the first portion of the bus; and

wherein the audio/video receiver includes:

a clock recovery circuit operable to receive the time stamp values and to produce a clock signal having a frequency associated with the received time stamp values; and

a synchronization signal detector coupled with the first portion of the bus and operable to receive the synchronization signal.

32. The home entertainment system of claim 31 wherein the first portion of the bus carries a power signal to the audio/video source and receiver.

33. The home entertainment system of claim 31 wherein the synchronization signal generator is included within the audio/video source.

34. The home entertainment system of claim 31 wherein the synchronization signal detector is a first synchronization signal detector, and wherein the audio/video source includes a second synchronization signal detector coupled with the first portion of the bus and operable to receive the synchronization signal.

35. The home entertainment system of claim 31, further comprising a transformer coupling the synchronization signal generator with the first portion of the bus.

36. The home entertainment system of claim 31, further comprising a transformer coupling the synchronization signal detector with the first portion of the bus.

37. The home entertainment system of claim 31 wherein the bus is an IEEE 1394 bus.

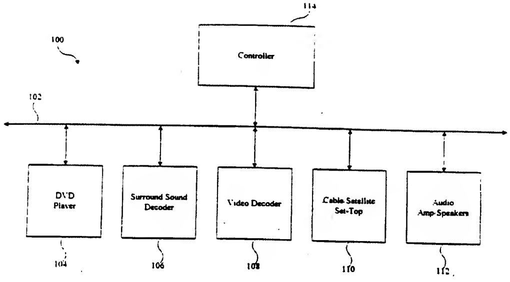


Fig. 1

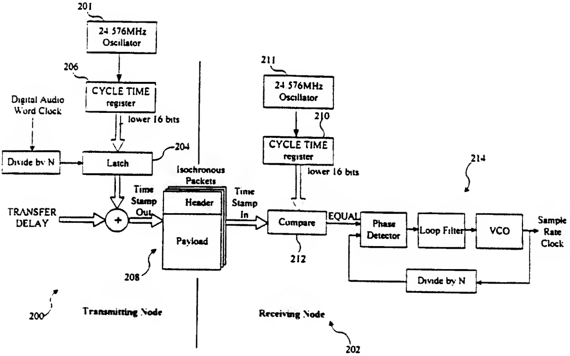


Fig. 2 (Prior Art)

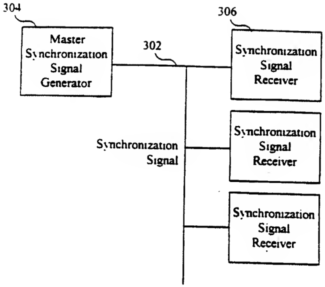


Fig. 3 (prior art)

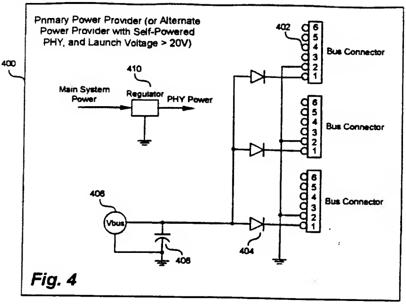
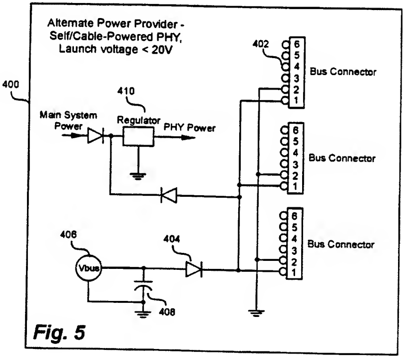

Pnmary Power Provider (or Alternate Power Provider with Self-Powered PHY, and Launch Voltage > 20V)
400
402
Bus Connector
410
Main System Power
Regulator
PHY Power
Bus Connector
406
Bus Connector
Vbus
404
408

Fig. 4


Alternate Power Provider - Self/Cable-Powered PHY, Launch voltage < 20V
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402
Bus Connector
410
Main System Power
Regulator
PHY Power
Bus Connector
406
404
Bus Connector
Vbus
408

Fig. 5

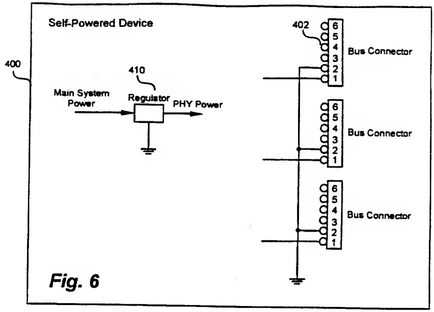
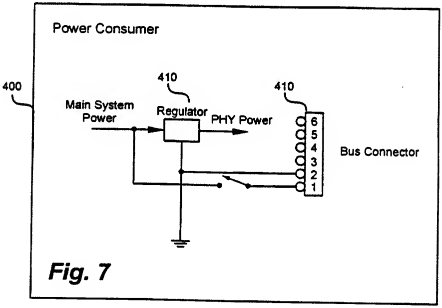

Self-Powered Device
400
410
402
Main System Power
Regulator
PHY Power
6
5
4
3
2
1
Bus Connector
Bus Connector
Bus Connector

Fig. 6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410
410
Main System Power
Regulator
PHY Power
6
5
4
3
2
1
Bus Connector

Fig. 7

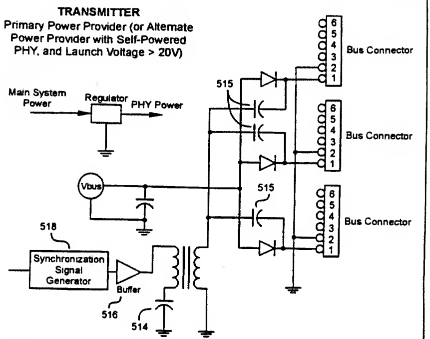

TRANSMITTER
Primary Power Provider (or Alternate Power Provider with Self-Powered PHY, and Launch Voltage > 20V)
Main System Power
Regulator
PHY Power
Vbus
515
515
518
Synchronization Signal Generator
Buffer
516
514
Bus Connector
Bus Connector
Bus Connector
6
5
4
3
2
1

Fig. 8

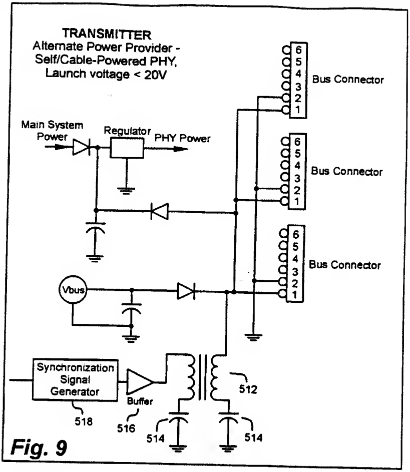

TRANSMITTER
Alternate Power Provider -
Self/Cable-Powered PHY,
Launch voltage < 20V
Main System Power
Regulator
PHY Power
Bus Connector
Bus Connector
Bus Connector
6
5
4
3
2
1
Vbus
Synchronization Signal Generator
Buffer
512
514
514
516
518

Fig. 9

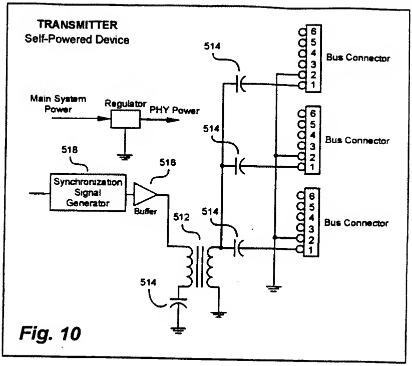

TRANSMITTER
Self-Powered Device
514
Bus Connector
Main System Power
Regulator
PHY Power
514
Bus Connector
518
516
Synchronization Signal Generator
Buffer
512
514
Bus Connector
514
6
5
4
3
2
1

Fig. 10

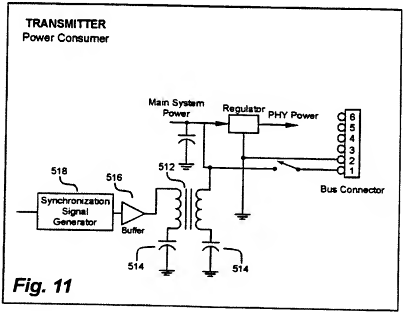

TRANSMITTER
Power Consumer
Main System Power
Regulator
PHY Power
512
518
516
Synchronization Signal Generator
Buffer
Bus Connector
514
514
6
5
4
3
2
1

Fig. 11

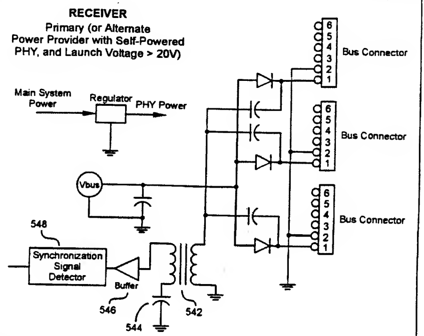

RECEIVER
Primary (or Alternate
Power Provider with Self-Powered
PHY, and Launch Voltage > 20V)
Main System Power
Regulator
PHY Power
Vbus
548
Synchronization Signal Detector
Buffer
546
544
542
Bus Connector
Bus Connector
Bus Connector
6
5
4
3
2
1

Fig. 12

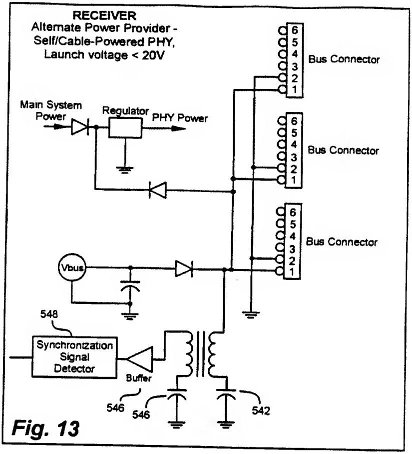
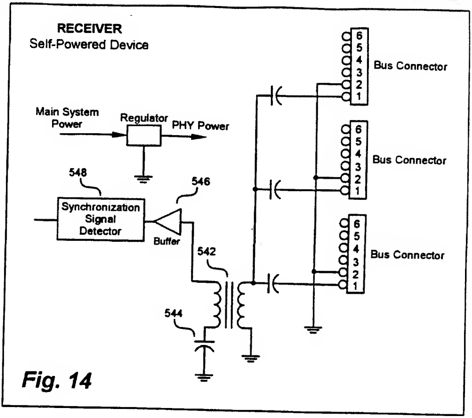

RECEIVER
Alternate Power Provider - Self/Cable-Powered PHY, Launch voltage < 20V
Main System Power
Regulator
PHY Power
Bus Connector
6
5
4
3
2
1
Bus Connector
6
5
4
3
2
1
Bus Connector
6
5
4
3
2
1
Vbus
548
Synchronization Signal Detector
Buffer
546
546
542

Fig. 13



RECEIVER
Self-Powered Device
Main System Power
Regulator
PHY Power
548
Synchronization Signal Detector
546
Buffer
542
544
Bus Connector
Bus Connector
Bus Connector
6
5
4
3
2
1

Fig. 14

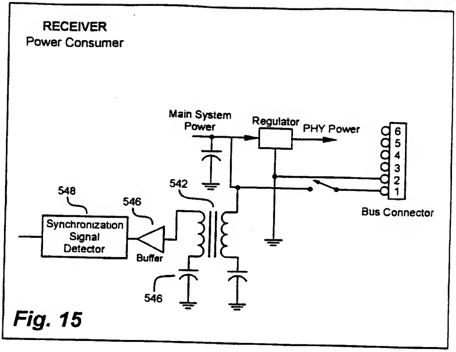

RECEIVER
Power Consumer
Main System Power
Regulator
PHY Power
6
5
4
3
2
1
Bus Connector
548
546
542
Synchronization Signal Detector
Buffer
546

Fig. 15

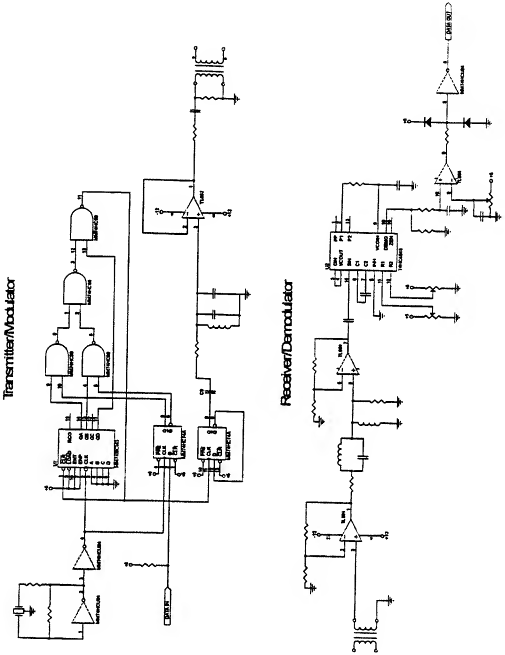


Figure 16

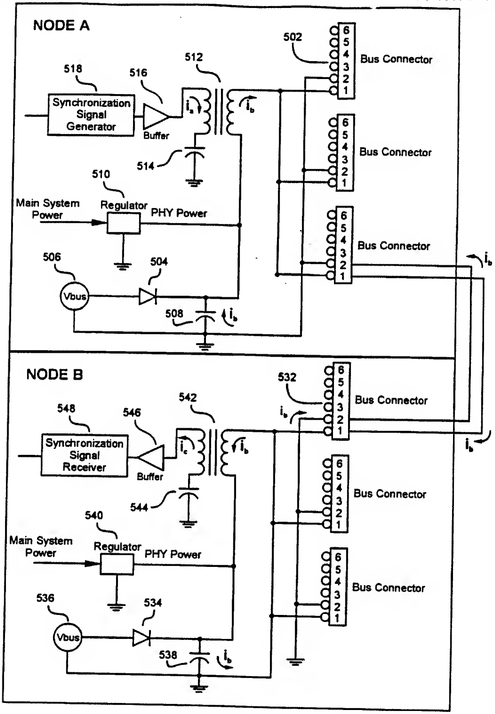

NODE A
502
Bus Connector
6
5
4
3
2
1
512
518
516
Synchronization Signal Generator
Buffer
514
510
Main System Power
Regulator
PHY Power
506
504
Vbus
508
NODE B
532
542
548
546
Synchronization Signal Receiver
Buffer
544
540
Main System Power
Regulator
PHY Power
536
534
Vbus
538

Fig. 17

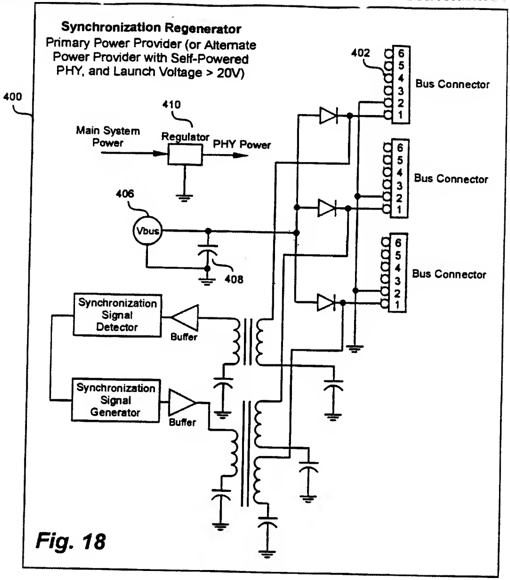

Synchronization Regenerator
Primary Power Provider (or Alternate Power Provider with Self-Powered PHY, and Launch Voltage > 20V)
400
402
410
Main System Power
Regulator
PHY Power
406
Vbus
408
Bus Connector
Bus Connector
Bus Connector
6
5
4
3
2
1
Synchronization Signal Detector
Buffer
Synchronization Signal Generator
Buffer

Fig. 18

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Published:
— *with international search report*

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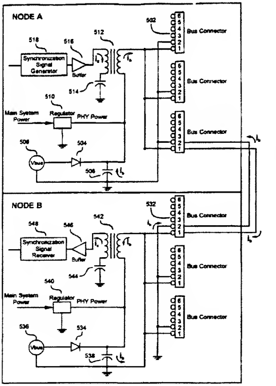
(54) Title: METHOD AND APPARATUS FOR DISTRIBUTED SYNCHRONIZATION SIGNAL



(57) Abstract: A method and apparatus is described for distributing a synchronization signal for deriving sample rate clocks in data transmitted between nodes in a system such as an IEEE 1394 bus-interconnected system. The synchronization signal is coupled onto a conductor of the IEEE 1394 bus by a clock master node, and received by all other nodes. The synchronization signal is coupled to the conductor in the bus without interfering with the signal, such as a power or data signal, carried by that conductor. Each node may derive its sample rate clocks using conventional time stamp means, or optionally referencing its sample rate clocks to the synchronization signal for higher performance. The format of the synchronization signal may be virtually any type of standard or non-standard work clock or longitudinal time code.

WO 01/22659 A3

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 00/26336

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G06F13/42 H04J3/06 H04L25/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04L H04J G06F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 819 051 A (MURRAY DAVID E ET AL) 6 October 1998 (1998-10-06) column 2, line 35 -column 3, line 9 column 5, line 41 -column 7, line 35 abstract; claims 1-13; figures 1,6-8	1,2,4,5, 8,9,20, 23-25,27
Y		11-17, 31-37
X	WO 99 35587 A (KONINKL PHILIPS ELECTRONICS NV ;PHILIPS SVENSKA AB (SE)) 15 July 1999 (1999-07-15) page 1, line 24 -page 5, line 2 page 8, line 1 -page 9, line 25	1,3,4, 6-10,20, 23,26-30
Y		11-17, 31-37

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 May 2001	07/06/2001

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Kalabic, F

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	BLOKS R H J: "The IEEE-1394 high speed serial bus" 1996 , PHILIPS JOURNAL OF RESEARCH,ELSEVIER, AMSTERDAM,NL, VOL. 50, NR. 1, PAGE(S) 209-216 XP004008212 ISSN: 0165-5817 the whole document ---	31-37
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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